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Production of customized reactors using 3D printing

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1. Introduction

The main advantage of 3D printing is the production of customized shapes that are not possible or that is very complicated to produce with other techniques. A technique like 3D printing takes process intensification to the next level, where control of topology allows us to produce targeted units and catalysts to specific reactions and separations.

The approach we have followed in different projects is to focus on challenging separations and reactions and approach them with a completely different view relating the design of the unit to the performance of the final device. The main advantages of this approach normally depend on the scale of application and also on the degree of optimization of the topology.

Exothermic and corrosive reactions are normally carried out in batch units manufactured with expensive steel alloys. Sometimes high dilution is used, and longer reaction time is necessary not because of the reaction but because of heat exchange. Such operating conditions are expensive because they result in requirement of additional units (separation) and/or more energy consumption. Moreover, they also possess a higher safety risk since more volume should be treated.

In this work we have designed a 3D printed reactor with enhanced heat transfer properties. Such properties are achieved by introducing lattices in the structure in order to enhance surface area of contact. Reactor characterization and operation has been done and compared with the benchmark case (batch reactor).

2. Methods

The reactor has been designed in Grasshopper, the parametric module of Rhinoceros software (McNeel, USA). The initial design was achieved by topology optimization for an increased surface area per unit volume using a genetic algorithm.

The design of the reactor was done in such a way that is possible to be printed by remote servers existing nowadays so that the generated stl has to comply with standards from such platforms in terms of resolution and size. The reactors were 3D printed in titanium (Grade 5). Characterization of heat transfer parameters and of mixing was done by standard techniques.

Mathematical modelling of the system was done using COMSOL (COMSOL AB, Sweden). Modelling of the process was done before manufacturing and after experiments were done in order to compare the effect of surface rugosity.

The reaction taking place is the sulfonation of cresol which is highly exothermic and if temperature is not controlled, it suffers from selectivity problems (multiple sulfonation of the aromatic ring).

3. Results and discussion

The 3D printed reactors designed and produced are shown in Figure 1. Four different units were printed: one without any internal lattice, one with only internal lattice (where fluids react), one with only external lattice and one with lattices in both sides.

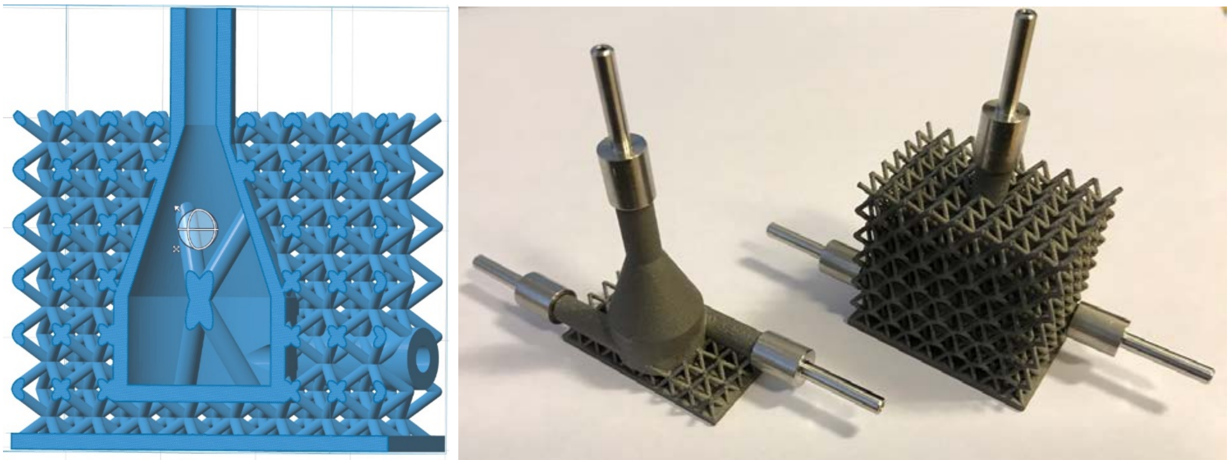

Figure 1. Design (left) and produced (right) 3D printed reactors for sulfonation of cresol.

When the reaction is done fast in a batch reactor, there is a fast temperature increase of 90K that has a very significant impact in selectivity. For this reason, this reaction has a high dilution. In the 3D printed reactors, the heat transfer coefficients are much higher allowing continuous operation.

Different experiments to calculate the heat transfer coefficient and to observe the micromixing in such reactors were done. Also, experiments with different flowrates and some dilution will be presented.

4. Conclusions

The possibility of generating customized shapes is the most important feature of 3D printing. Using such a tool for the intensification of reactors is only starting but has already demonstrated a big potential. In our case, the reactors were designed with an important constraint: they should be printable through remote platforms, once that this is a constrain that any industry that wants to implement 3D printing has nowadays.

Our design is similar to a Hartridge-Roughton mixer but with lattices to enhance heat transfer coefficients. The unit was produced in titanium which is a material appropriate to perform this reaction.

Initial results obtained indicate that this is a good methodology to produce customized models for targeted chemicals.